NP series
maintenance-free
rechargeable
battery

Application Manual

YUASA BATTERY CO., LTD.

CONTENTS

PAGE

INTRODUCTION 1

APPLICATIONS 1

TECHNICAL FEATURES 1

YUASA NP BATTERY CONSTRUCTION 2

CHEMICAL REACTION IN A SEALED LEAD ACID BATTERY 3

DESIGN/APPLICATION TIPS TO ASSURE MAXIMUM SERVICE 3

GENERAL SPECIFICATIONS 4

BATTERY CAPACITY SELECTION 5

DISCHARGING 5
- Discharge Characteristics 5
- Temperature Characteristics 7
- Storage, Self Discharge and Shelf Life 8
- Capacity Available Measured by Open Circuit Voltage 9

OVERDISCHARGE (DEEP DISCHARGE) 9

IMPEDANCE 9

CHARGING 10
- Constant Voltage Charging 10
- Initial Charge Current Limit 13
- Constant Current Charging 14
- Taper Charging 15
- Recommended Charging Circuits 15
- YUASA C.V.C.C. Constant Voltage Constant Current Charge Unit 17
- Charger Output Regulation and Accuracy 18
- Top Charge 18
- Recovery Charge After Deep Discharge 19
- Temperature Compensation 19
- Charge Efficiency 20
- Solar Powered Chargers 21

EXPECTED SERVICE LIFE OF NP BATTERIES 22
- Cycle Service Life 22
- Float (Standby) Service Life 22

PERIODIC SYSTEM CHECK 23

PARALLEL CONNECTIONS 23

GLOSSARY 24

INTRODUCTION

Yuasa began development of the NP Series of maintenance free sealed lead acid batteries in 1958. Today's NP battery is the culmination of over 65 years of battery manufacturing experience.

The high energy density, advanced plate technology, fully sealed construction, efficient performance in float or cyclic services, and long service life combine to make Yuasa NP batteries the most reliable and versatile maintenance free rechargeable sealed lead acid batteries available.

APPLICATIONS

Yuasa NP series batteries are designed for use in both cyclic and float applications. The high energy density to weight ratio coupled with a wide selection of sizes and configurations make NP batteries the logical choice for numerous applications.

A partial list of common applications includes, but is not limited to, standby or primary power for:

- Alarm Systems
- Cable Television
- Communications Equipment
- Control Equipment
- Computers
- Electronic Cash Registers
- Electronic Test Equipment
- Electric Powered Wheelchairs
- Emergency Lighting Systems
- Fire & Security Systems
- Geophysical Equipment
- Marine Equipment
- Medical Equipment
- Micro Processor Based Office Machines
- Portable Cine & Video Lights
- Power Tools
- Solar Powered Systems
- Telecommunications Systems
- Television & Video Recorders
- Toys
- Uninterruptible Power Supplies
- Vending Machines

TECHNICAL FEATURES

Sealed Construction

Yuasa's unique construction and sealing technique guarantee that no electrolyte leakage can occur from the terminals or case of any NP battery. This feature insures safe, efficient operation of NP batteries in any position. Yuasa NP batteries are classified as "Non-Spillable" and will meet all requirements of the International Air Transport Association.

Electrolyte Suspension System

All Yuasa NP batteries utilize an electrolyte suspension system consisting of a glass fibre separator material. This suspension system allows maximum life and service, while preventing any electrolyte from being outside of the separator material. No silica gels or other contaminants are used.

Gas Generation

Yuasa NP batteries incorporate a unique Yuasa design that effectively controls generation of gas and allows recombination within the battery of over 99% of gas generated during normal usage.

Maintenance-Free Operation

During the expected five (5) year float service life of NP batteries there is no need to check the specific gravity of the electrolyte, or add water. In fact, there is no provision for these maintenance functions.

Operation In Any Position

The combination of sealed construction and Yuasa's electrolyte suspension system permit operation of NP batteries in any position without loss of capacity, electrolyte, or service life.

Low Pressure Venting System

Yuasa NP batteries are equipped with a safe, low pressure venting system designed to release excess gas and reseal automatically in the event that gas pressure rises to a level above the normal rate. Thus, there is no excessive buildup of gas in the batteries. This low pressure venting system, coupled with the extraordinarily high recombination efficiency, make Yuasa NP batteries the safest sealed lead-acid batteries available.

Heavy Duty Grids

The heavy duty lead calcium-alloy grids in NP batteries provide an extra margin of performance and service life in both float and cyclic applications, even in conditions of deep discharge.

Cyclic Service Life

Depending upon the average depth of discharge, over 1,000 discharge/recharge cycles can be expected from NP batteries.

Float Service Life

The expected service life of NP batteries used in float (trickle charge) service is 4 to 5 years.

Separators

The use of glass fibre separators in NP batteries provides extremely reliable, efficient insulation between the plates and prevents inter-plate shorting or loss of active material from the plates.

Low Self Discharge — Long Shelf Life

At room temperature the self discharge rate of Yuasa NP batteries is approximately 3% of rated capacity per

month. This low self discharge rate and the NP batteries' excellent charging characteristics permit storage for up to one (1) year without loss of efficiency or any appreciable deterioration of battery performance.

Operating Temperature Range
Yuasa NP batteries may be used over a broad range of ambient temperatures, permitting considerable flexibility in system design and location.

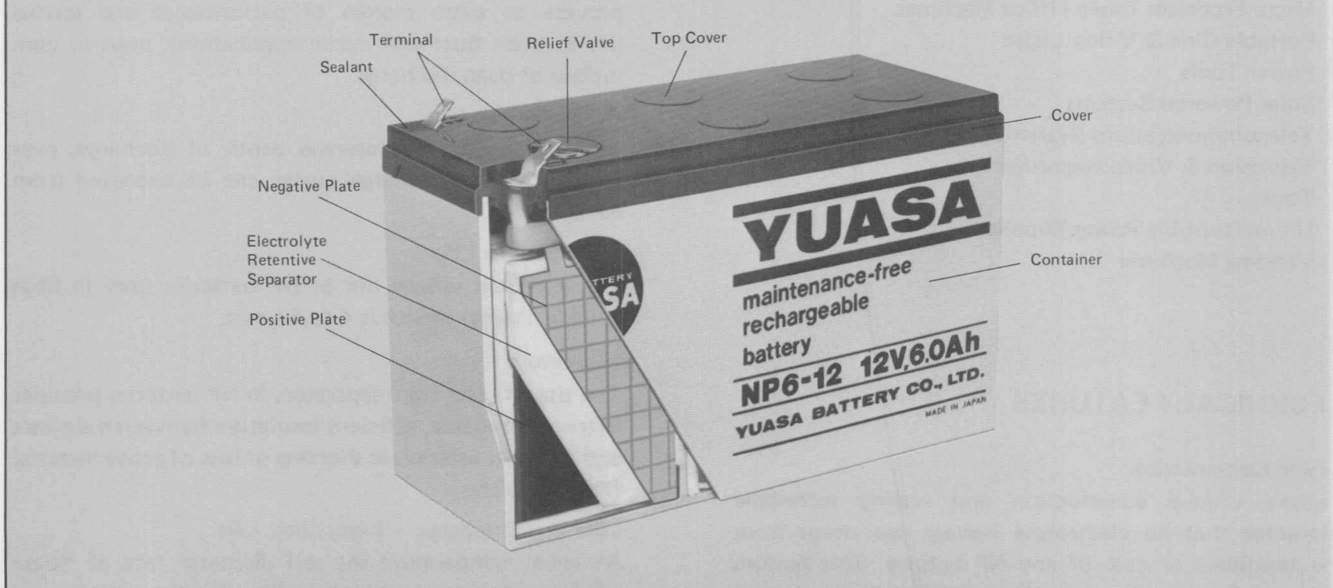
YUASA NP BATTERY CONSTRUCTION

1. **Plates**
   Both the positive and negative plates are made of Lead Calcium alloy grids. Their special design allows the use of highly efficient active materials, which result in consistent high energy density, and specific energy.
2. **Separators**
   The glass fibre separators in NP batteries have high ionic conductivity, high resistance to acid and excellent thermal characteristics. The high porosity of the separators allows free access of electrolyte to the active materials in the plates which contributes to the uniformally excellent charging and discharging characteristics of NP batteries.
3. **Venting System**
   The venting system, which operates at 7 psi to 10 psi, is designed to release excess gas and keep the internal pressure within the optimum range of safe, efficient performance.

High Recovery Capability
Yuasa NP batteries have excellent charge acceptance and recovery capability, even after very deep discharge.

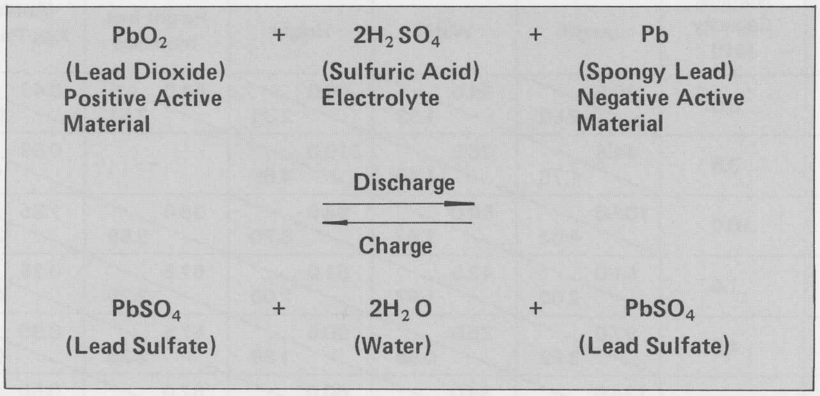
4. **Cover**
   Joints between the cover and the case provide a long, consistent path for perfect positive sealing.
5. **Terminals**
   Terminals on NP batteries vary according to the capacity, or in some instances, the intended use of the specific model. Depending on the battery model the terminals may be solderless Amp Faston, Amp Mate-N-Lok on wire leads, or bolt and nut. To determine the type and size of standard terminal for specific battery models, please refer to the chart of General Specifications on page 4.
6. **Sealant**
   A specially formulated sealant prevents leakage through the terminals. To further support the integrity of the hermetic sealing, a unique mechanical design provides elaborate terminal-end protection.
7. **Container**
   The case and cover are manufactured from high impact ABS plastic resin. All Yuasa NP batteries are black and grey.

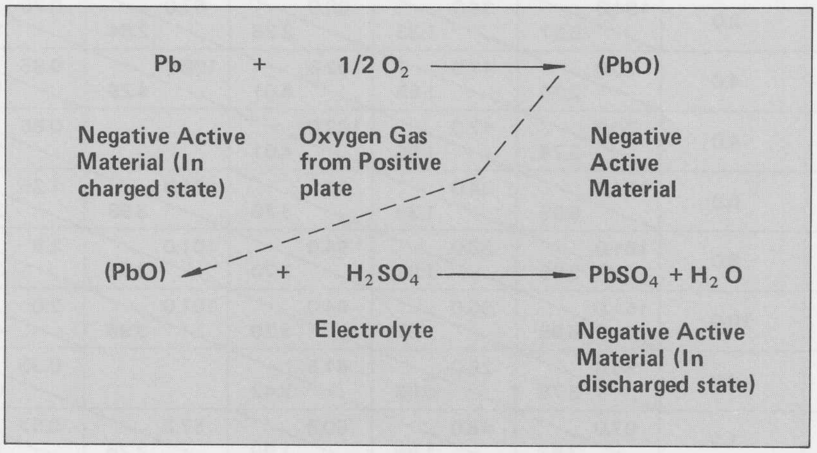
CONSTRUCTION OF YUASA NP BATTERY



CHEMICAL REACTION IN A SEALED LEAD-ACID BATTERY

The chemical reaction which takes place in a Yuasa NP sealed lead-acid battery is expressed in the following equation:





Gas Recombination

In addition to the above chemical reaction, at the final stage of charging, a reaction takes place which is referred to as gas recombination. This is a reaction in which oxygen gas generated from the positive plates due to overcharge is absorbed into the negative plates. Each cell of each NP battery contains an extra negative plate which results in extraordinarily high recombination efficiency.

DESIGN/APPLICATION TIPS TO ASSURE MAXIMUM SERVICE

Yuasa NP batteries are highly efficient maintenance free electrochemical systems designed to provide years of trouble-free electrical energy. The performance and service life of these batteries can be maximized by observing the following guidelines:

1. Heat kills batteries. Avoid placing batteries in close proximity to heat sources of any kind. The longest service life will be attained when the battery is operated over an ambient temperature range of 20°C (68°F) to 25°C (77°F).
2. Recharge the battery fully immediately after each discharge.
3. Overdischarging, that is, discharging a battery beyond the 100% capacity level, is generally of no practical use and is very detrimental to the life of the battery.
4. Overcharging serves no useful purpose and will result in sacrifice of a battery's service life. Similarly, undercharging is detrimental and can shorten the service life of a battery.
5. The use of constant voltage, current limited charging is highly recommended to avoid either overcharging or undercharging of sealed lead-acid batteries.
6. Do not short circuit a battery.
7. When connecting batteries in series, all batteries in the series group must have the same capacity rating.

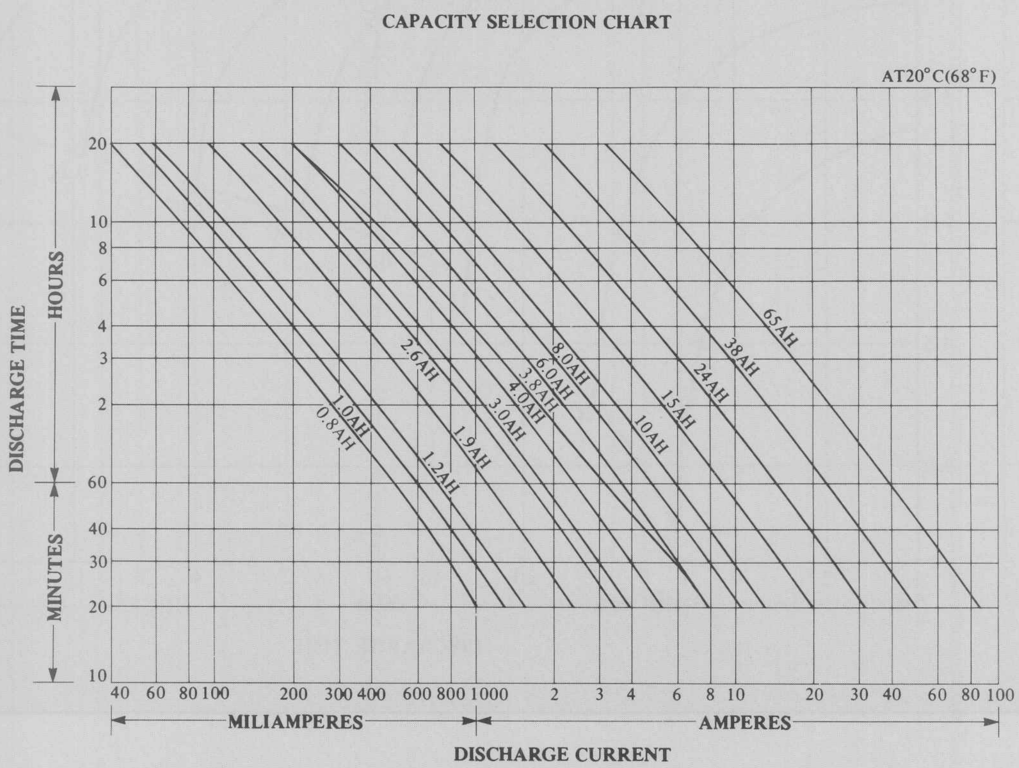
GENERAL SPECIFICATIONS

Battery Type	Nominal Voltage (V)	20 Hour Rate Nominal Capacity (AH)	Dimensions (mm/inches) Length	Width	Height	Height Incl. Terminals	Weight (Approx.) Kgs/Pounds	Terminal Type
NP 3 – 4	4	3.0	90.5 / 3.56	34.0 / 1.33	60.0 / 2.36	64.0 / 2.51	0.43 / 0.94	Faston Tab. 187
NP 3.8 – 4H	4	3.8	44.8 / 1.76	35.5 / 1.40	119.0 / 4.69	–	0.53 / 1.17	Flat Contact
NP 10 – 4	4	10.0	102.0 / 4.02	50.0 / 1.97	94.0 / 3.70	98.0 / 3.85	1.35 / 2.97	Faston Tab. 250
NP 1 – 6	6	1.0	51.0 / 2.00	42.5 / 1.67	51.0 / 2.00	57.5 / 2.26	0.25 / 0.55	Faston Tab. 187
NP 1.2 – 6	6	1.2	97.0 / 3.82	25.0 / 0.98	50.5 / 1.99	57.5 / 2.26	0.30 / 0.66	Faston Tab. 187
NP 2.6 – 6	6	2.6	134.0 / 5.27	34.0 / 1.33	60.0 / 2.36	67.0 / 2.64	0.56 / 1.23	Faston Tab. 187
NP 3 – 6	6	3.0	134.0 / 5.27	34.0 / 1.33	60.0 / 2.36	67.0 / 2.64	0.70 / 1.54	Faston Tab. 187
NP 4 – 6	6	4.0	70.0 / 2.76	47.0 / 1.85	102.0 / 4.01	109.0 / 4.29	0.85 / 1.87	Faston Tab. 187
NP 4 – 6W	6	4.0	70.0 / 2.76	47.0 / 1.85	102.0 / 4.01	–	0.85 / 1.87	AMP MATE-N-LOK®
NP 6 – 6	6	6.0	151.0 / 5.95	34.0 / 1.33	94.0 / 3.70	101.0 / 3.98	1.25 / 2.75	Faston Tab. 187
NP 8 – 6	6	8.0	151.0 / 5.95	50.0 / 1.97	94.0 / 3.70	101.0 / 3.98	1.8 / 3.96	Faston Tab. 187
NP 10 – 6	6	10.0	151.0 / 5.95	50.0 / 1.97	94.0 / 3.70	101.0 / 3.98	2.0 / 4.41	Faston Tab. 187
NP 0.8 – 12	12	0.8	96.0 / 3.78	25.0 / 0.98	61.5 / 2.42	–	0.35 / 0.77	JST VH CONNECTOR
NP 1.2 – 12	12	1.2	97.0 / 3.82	48.0 / 1.89	50.5 / 1.99	57.5 / 2.26	0.57 / 1.25	Faston Tab. 187
NP 1.9 – 12	12	1.9	178.0 / 7.01	34.0 / 1.33	60.0 / 2.36	67.0 / 2.64	0.83 / 1.83	Faston Tab. 187
NP 2.6 – 12	12	2.6	134.0 / 5.27	67.0 / 2.64	60.0 / 2.36	67.0 / 2.64	1.12 / 2.47	Faston Tab. 187
NP 4 – 12	12	4.0	90.0 / 3.54	70.0 / 2.75	102.0 / 4.01	106.0 / 4.17	1.7 / 3.74	Faston Tab. 187
NP 6 – 12	12	6.0	151.0 / 5.95	65.0 / 2.56	94.0 / 3.70	101.0 / 3.98	2.4 / 5.28	Faston Tab. 187
NP 15 – 12	12	15.0	181.0 / 7.12	76.0 / 2.99	167.0 / 6.57	–	5.9 / 13.0	Bolt Terminal
NP 24 – 12	12	24.0	166.0 / 6.54	175.0 / 6.89	125.0 / 4.92	–	8.65 / 19.1	Faston Tab. 250
NP 24 – 12B	12	24.0	166.0 / 6.54	175.0 / 6.89	125.0 / 4.92	–	8.65 / 19.1	Bolt Terminal
NP 38 – 12	12	38.0	197.0 / 7.75	165.0 / 6.50	170.0 / 6.69	–	13.8 / 30.4	Bolt Terminal
NP 65 – 12	12	65.0	350.0 / 13.78	166.0 / 6.53	174.0 / 6.85	–	22.8 / 50.2	Bolt Terminal

BATTERY CAPACITY SELECTION

Figure 1 below may be used to determine the minimum battery size, expressed in Ampere Hours of capacity, for a specific application. To determine the capacity required, specify the discharge current required and the length of time required for discharge. Find the specified current and time on the chart. The point where the current and time lines intersect on the chart with the diagonal AH line is the minimum capacity required for the application. In addition, it is recommended that Figures 29 (Cyclic Service Life) and 30 (Float Service Life), and the individual battery model specification sheet be consulted prior to final selection.

Figure 1. 20-HOUR RATE CAPACITY SELECTION CHART



DISCHARGING

Discharge Characteristics

The curves shown in Figures 1 and 2, and the discharge rates shown in Tables 1 and 2 illustrate the typical discharge characteristics of Yuasa NP batteries at an ambient temperature of 20°C (68°F). The symbol "C" expresses the nominal capacity of the battery measured at a 20-Hour discharge rate. Please refer to General Specifications on page 4 to determine the nominal capacity rating of specific NP models. The standard industry practice to determine the nominal capacity of a maintenance free sealed lead-acid battery is to discharge a battery at a 20-Hour rate to final voltage of 1.75 volts per cell.

The curves in Figure 2 show currents that can be drawn at different discharge capacity rates at an ambient temperature of 20°C (68°F).

Tables 1 and 2 clearly illustrate that the rated nominal capacity when a battery is discharged at a rate higher than the 20-Hour discharge rate. This should be taken into consideration when selecting a battery for an application.

Figure 2. **DISCHARGE CHARACTERISTIC CURVES**

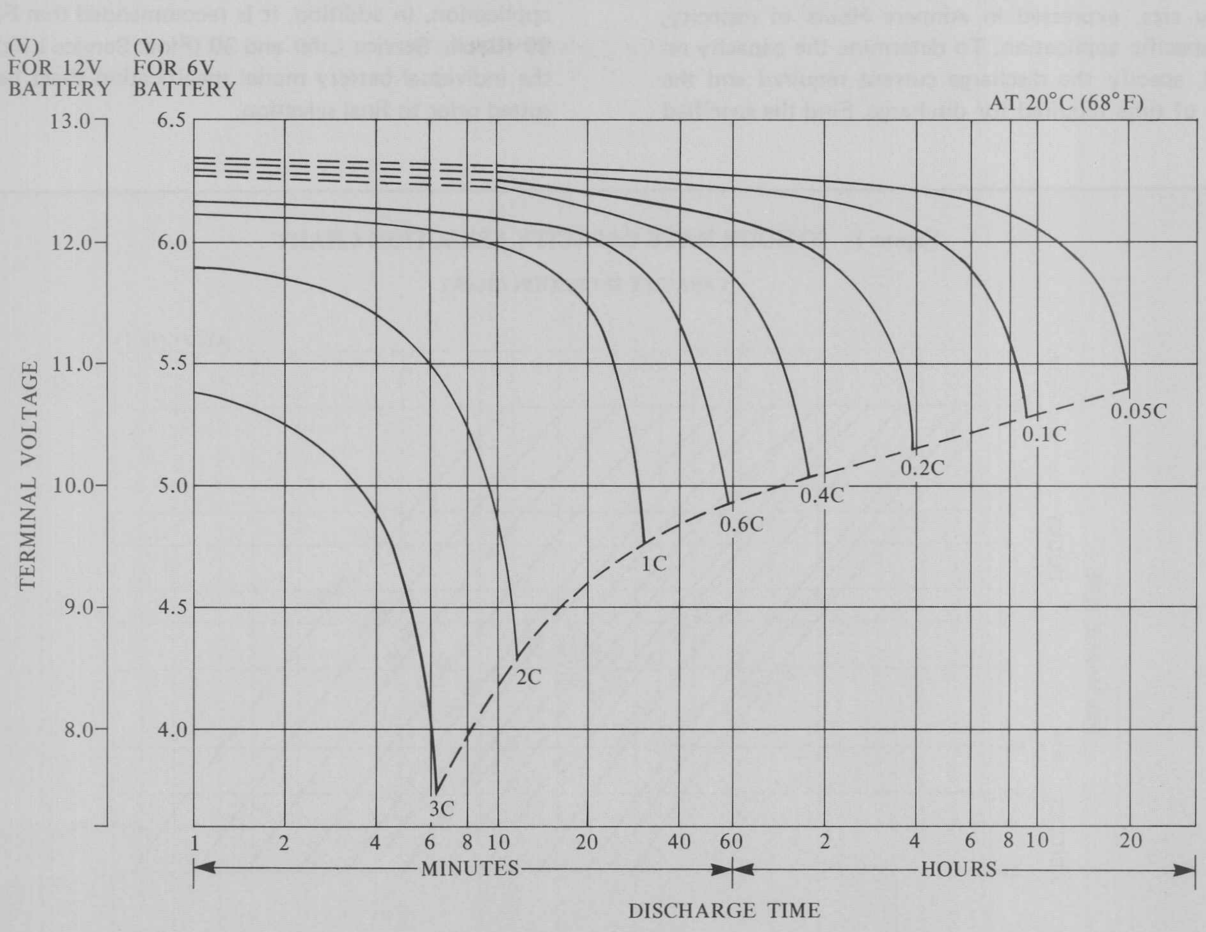


Table 1. DISCHARGE CURRENT AT STIPULATED DISCHARGE RATES

20 H.R. Capacity	Discharge Current							
	0.05C	0.1C	0.2C	0.4C	0.6C	1C	2C	3C
0.8Ah	0.04A	0.08A	0.16A	0.32A	0.48A	0.8A	1.6A	2.4A
1.0	0.05	0.10	0.20	0.40	0.60	1.0	2.0	3.0
1.2	0.06	0.12	0.24	0.48	0.72	1.2	2.4	3.6
1.9	0.095	0.19	0.38	0.78	1.14	1.9	3.8	5.7
2.6	0.13	0.26	0.52	1.04	1.56	2.6	5.2	7.8
3.0	0.15	0.30	0.60	1.20	1.80	3.0	6.0	9.0
3.8	0.19	0.38	0.76	1.52	2.28	3.8	7.6	11.4
4.0	0.20	0.40	0.80	1.60	2.40	4.0	8.0	12.0
6.0	0.30	0.60	1.20	2.40	3.60	6.0	12.0	18.0
8.0	0.40	0.80	1.60	3.20	4.80	8.0	16.0	24.0
10.0	0.50	1.00	2.00	4.00	6.00	10.0	20.0	30.0
15.0	0.75	1.50	3.00	6.00	9.00	15.0	30.0	45.0
24.0	1.20	2.40	4.80	9.60	14.40	24.0	48.0	72.0
38.0	1.90	3.80	7.60	15.20	22.80	38.0	76.0	114.0
65.0	3.25	6.50	13.00	26.00	39.0	65.0	130.0	195.0

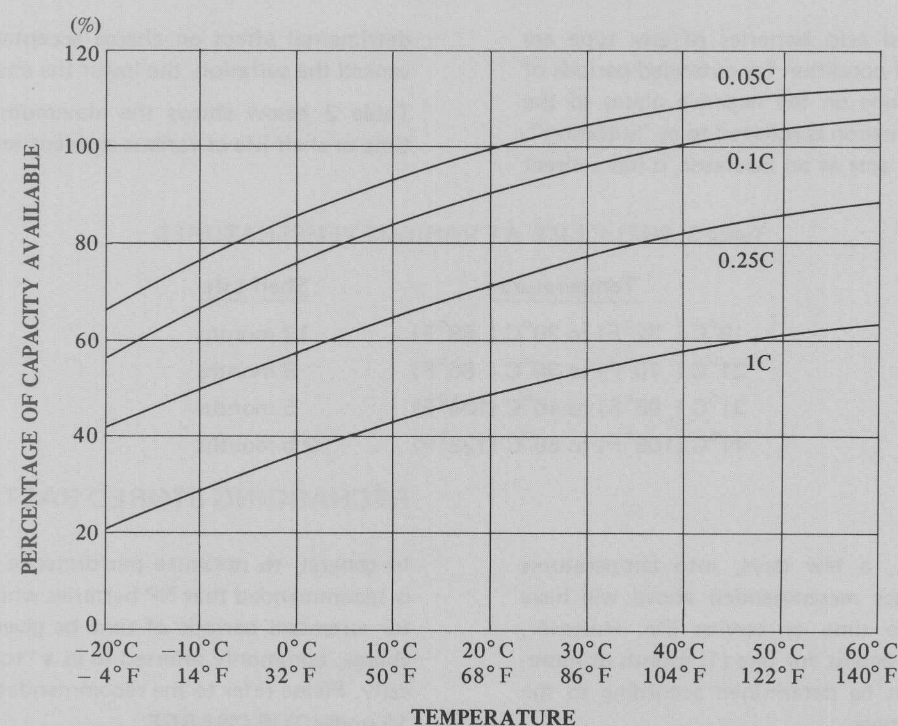
Table 2 DISCHARGE CAPACITY AT VARIOUS DISCHARGE RATES

20 H.R. Capacity	Discharge Capacity				
	20 H.R.	10 H.R.	5 H.R.	3 H.R.	1 H.R.
	0.05CA to 1.75V/C	0.093CA to 1.75V/C	0.17CA to 1.70V/C	0.25CA to 1.67V/C	0.60CA to 1.55V/C
0.8Ah	0.8Ah	0.74Ah	0.68Ah	0.62Ah	0.48Ah
1.0	1.0	0.93	0.85	0.77	0.60
1.2	1.2	1.1	1.0	0.9	0.7
1.9	1.9	1.8	1.6	1.5	1.1
2.6	2.6	2.4	2.2	2.0	1.6
3.0	3.0	2.8	2.6	2.3	1.8
3.8	3.8	3.5	3.2	2.9	2.3
4.0	4.0	3.7	3.4	3.1	2.4
6.0	6.0	5.6	5.1	4.6	3.6
8.0	8.0	7.4	6.8	6.2	4.8
10.0	10.0	9.3	8.5	7.7	6.0
15.0	15.0	14.0	12.8	11.6	9.0
24.0	24.0	22.3	20.4	18.5	14.4
38.0	38.0	35.0	32.3	29.3	22.8
65.0	65.0	60.5	55.2	50.1	39.0

TEMPERATURE CHARACTERISTICS

At higher temperatures, the electrical capacity that can be taken out of a battery increases. At lower temperatures, the electrical capacity that can be taken out of a battery decreases. Figure 3 shows the temperature effects in relation to battery capacity.

Figure 3. TEMPERATURE EFFECTS IN RELATION TO BATTERY CAPACITY

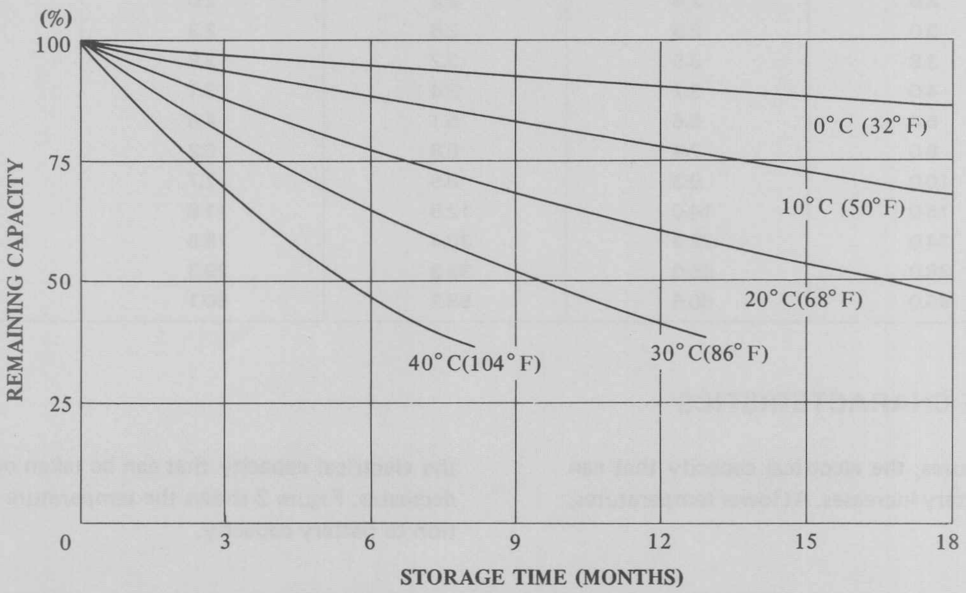


STORAGE, SELF-DISCHARGE and SHELF LIFE

The self-discharge rate of NP batteries is approximately 3% per month when batteries are stored at an ambient temperature of 20°C (68°F). The self-discharge rate will vary as a function of ambient storage temperature.

Figure 4 shows the relationship between storage times at various temperatures and the remaining capacity.

Figure 4. SELF DISCHARGE CHARACTERISTICS



In general, when lead acid batteries of any type are stored in a discharged condition for extended periods of time, lead sulfate forms on the negative plates of the batteries. This phenomenon is referred to as "sulfation". Since the lead sulfate acts as an insulator, it has a direct detrimental effect on charge acceptance. The more advanced the sulfation, the lower the charge acceptance.

Table 3 below shows the maximum allowable storage time or shelf life at various ambient temperatures.

Table 3 SHELF LIFE AT VARIOUS TEMPERATURES

Temperature	Shelf Life
0°C (32°F) to 20°C (68°F)	12 months
21°C (70°F) to 30°C (86°F)	9 months
31°C (88°F) to 40°C (104°F)	5 months
41°C (106°F) to 50°C (122°F)	2.5 months

Brief excursions, i.e., a few days, into temperatures higher than the ranges recommended above will have no effect on storage time or service life. However, should the excursion persist for one (1) month or more, the storage time must be determined according to the new ambient temperature.

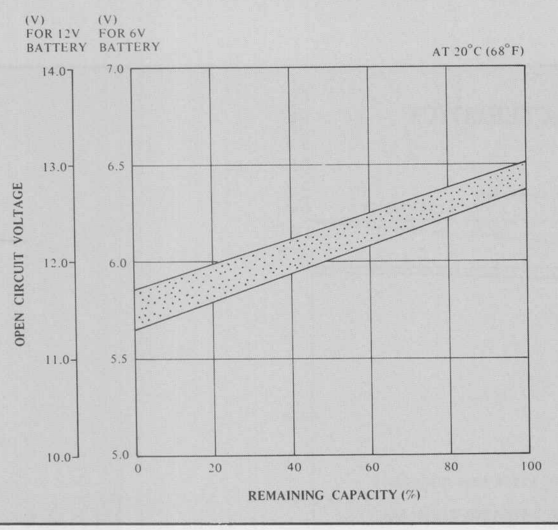
RECHARGING STORED BATTERIES

In general, to optimize performance and service life, it is recommended that NP batteries which are to be stored for extended periods of time be given a supplementary charge, commonly referred to as a "top charge", periodically. Please refer to the recommendations listed on page 18 under TOP CHARGE.

CAPACITY AVAILABLE MEASURED BY OPEN CIRCUIT VOLTAGE

The approximate depth of discharge, or remaining capacity, in a Yuasa NP battery can be empirically determined by referring to Figure 5.

Figure 5. OPEN CIRCUIT VOLTAGE VS REMAINING CAPACITY



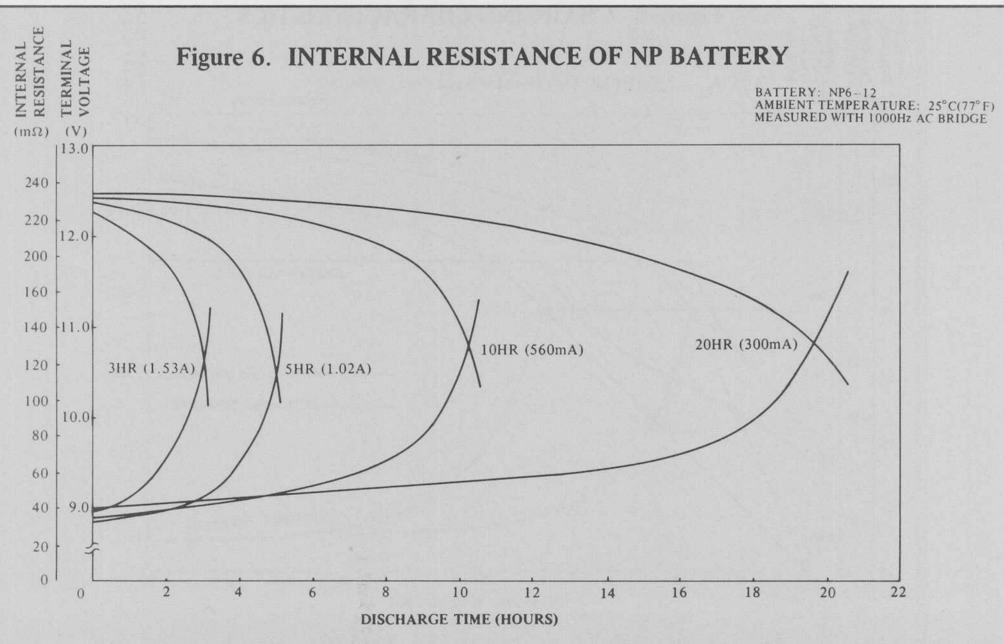
OVERDISCHARGE (DEEP DISCHARGE)

The dotted line in Figure 2 indicates the lowest recommended voltage under load, or cut-off voltage, for NP batteries at various discharge rates. In general, lead-acid batteries are damaged in terms of capacity and service life if discharged below the recommended cut-off voltages. It is generally recognized that all lead calcium alloy grid batteries are subject to overdischarge damage.
For example, if a lead-acid battery was discharged to zero (0) volts, and left standing in either open circuit or closed circuit for a long period of time, severe sulfation would occur, raising the internal resistance of the battery abnormally high. In such an extreme case, the battery may not accept a charge.
However, Yuasa NP batteries have been designed to withstand overdischarge. While it is not recommended that the batteries be subjected to frequent overdischarge, Yuasa NP batteries can recover full capacity under normal charging conditions, even when they have been subjected to extreme overdischarge in closed circuit.

IMPEDANCE

The internal resistance (impedance) of a battery is lowest when the battery is in a fully charged state. The internal resistance increases gradually during discharge, and rises abruptly at the final stage of discharge.
Figure 6 shows the internal resistance of an NP battery measured through a 1,000 Hz AC bridge.

Figure 6. INTERNAL RESISTANCE OF NP BATTERY



CHARGING

Proper charging is one of the most important factors to consider when using maintenance free sealed lead-acid batteries. Battery performance and service life will be directly effected by the efficiency of the charger selected. The three basic charging methods are:

i) Constant Voltage Charging
ii) Constant Current Charging
iii) Taper Charging

CONSTANT VOLTAGE CHARGING

Constant voltage charging is the most suitable, and commonly used method for charging sealed lead-acid batteries. Figures 7 – 12 show the charging characteristics of NP batteries when charged by constant voltage chargers at 2.30 volts/cell, 2.40 volts/cell and 2.50 volts/cell, when the initial charging current is controlled at 0.1CA, and 0.25CA.

Figure 7. CHARGING CHARACTERISTICS

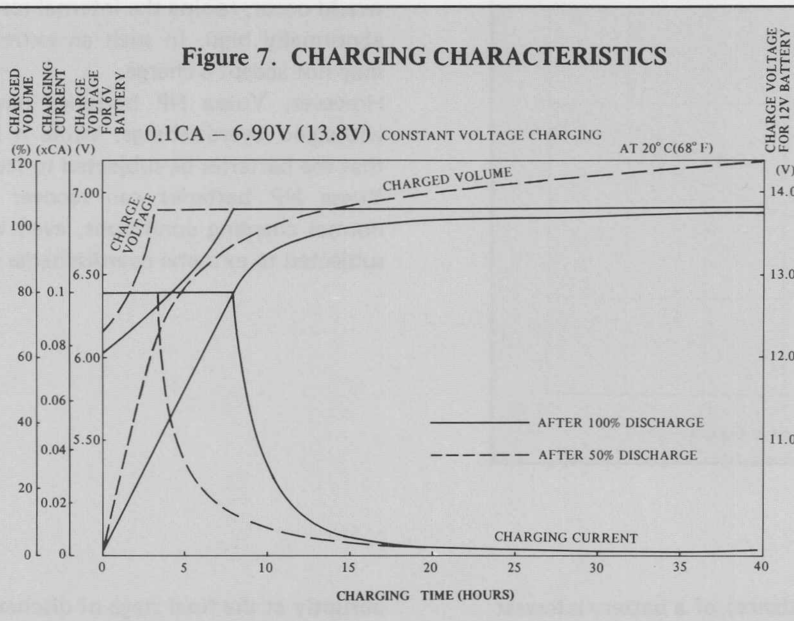


Figure 8. CHARGING CHARACTERISTICS

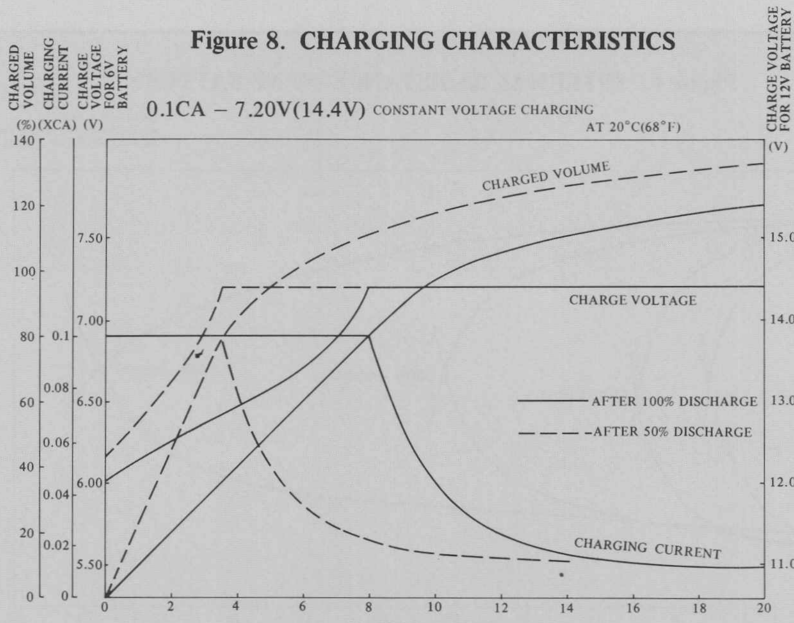


Figure 9. CHARGING CHARACTERISTICS

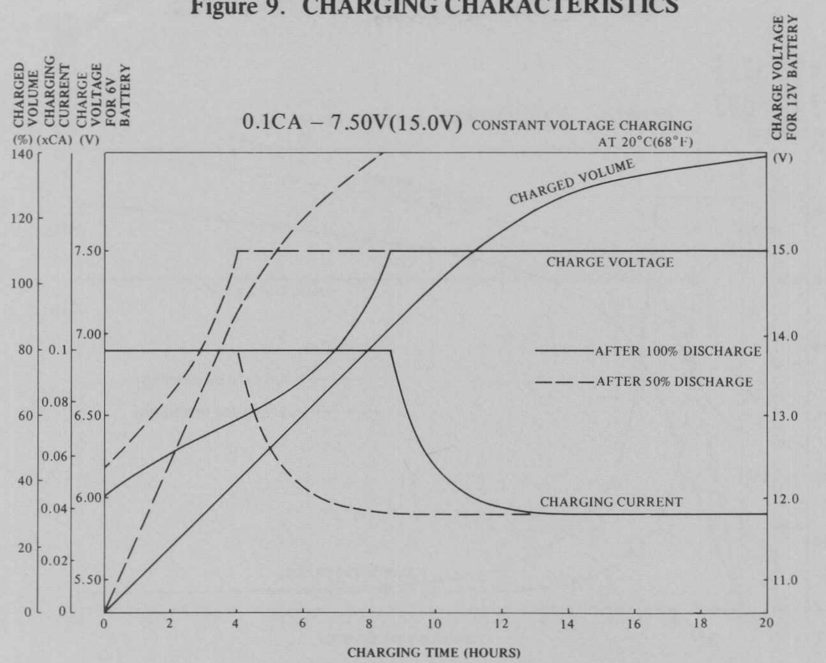
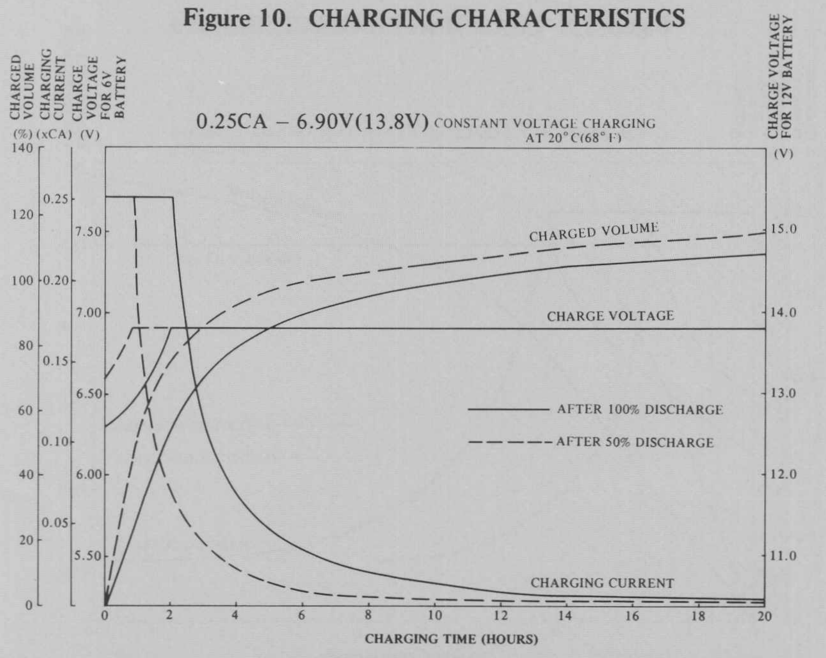


Figure 10. CHARGING CHARACTERISTICS



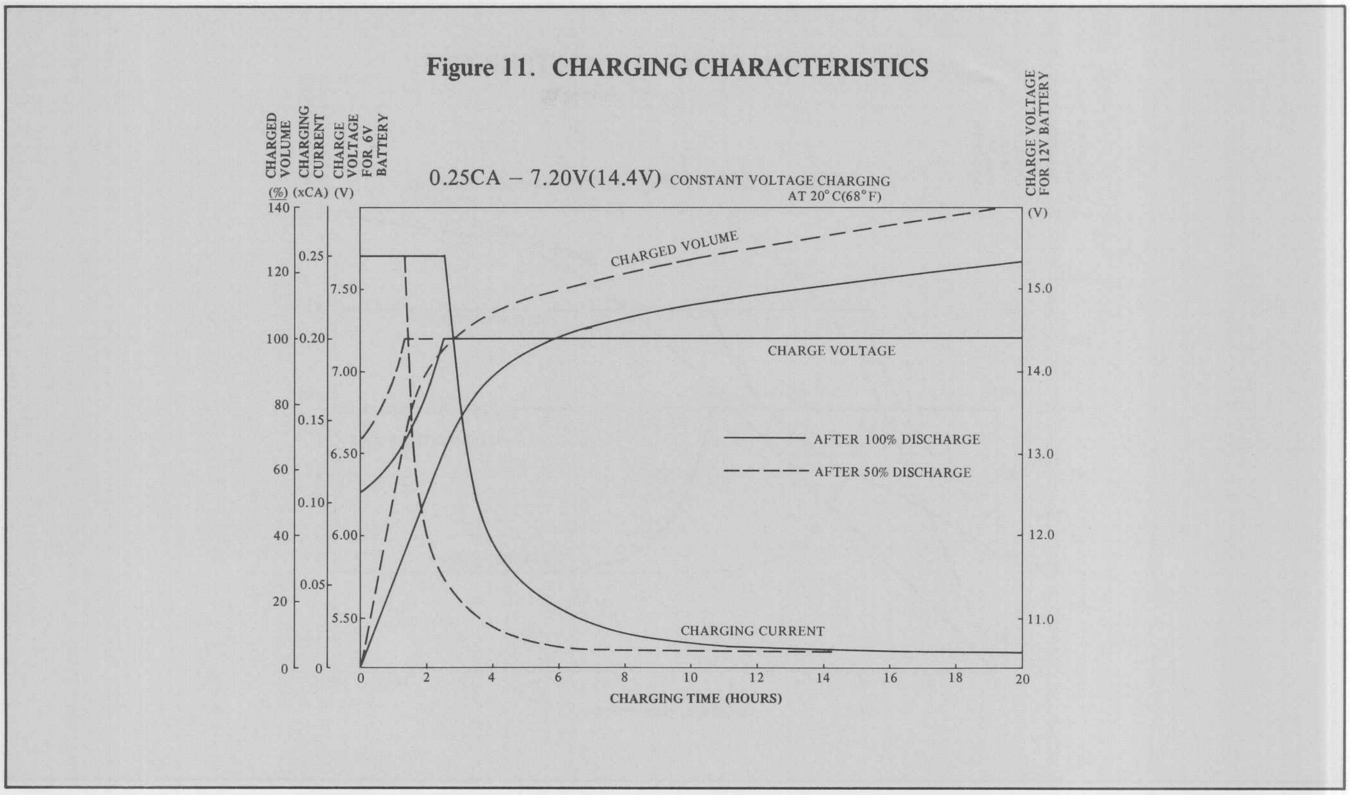


Figure 11. CHARGING CHARACTERISTICS
0.25CA – 7.20V(14.4V) CONSTANT VOLTAGE CHARGING
AT 20°C(68°F)
CHARGED VOLUME (%)
CHARGING CURRENT (xCA)
CHARGE VOLTAGE FOR 6V BATTERY (V)
CHARGE VOLTAGE FOR 12V BATTERY (V)
CHARGED VOLUME
CHARGE VOLTAGE
CHARGING CURRENT
AFTER 100% DISCHARGE
AFTER 50% DISCHARGE
CHARGING TIME (HOURS)

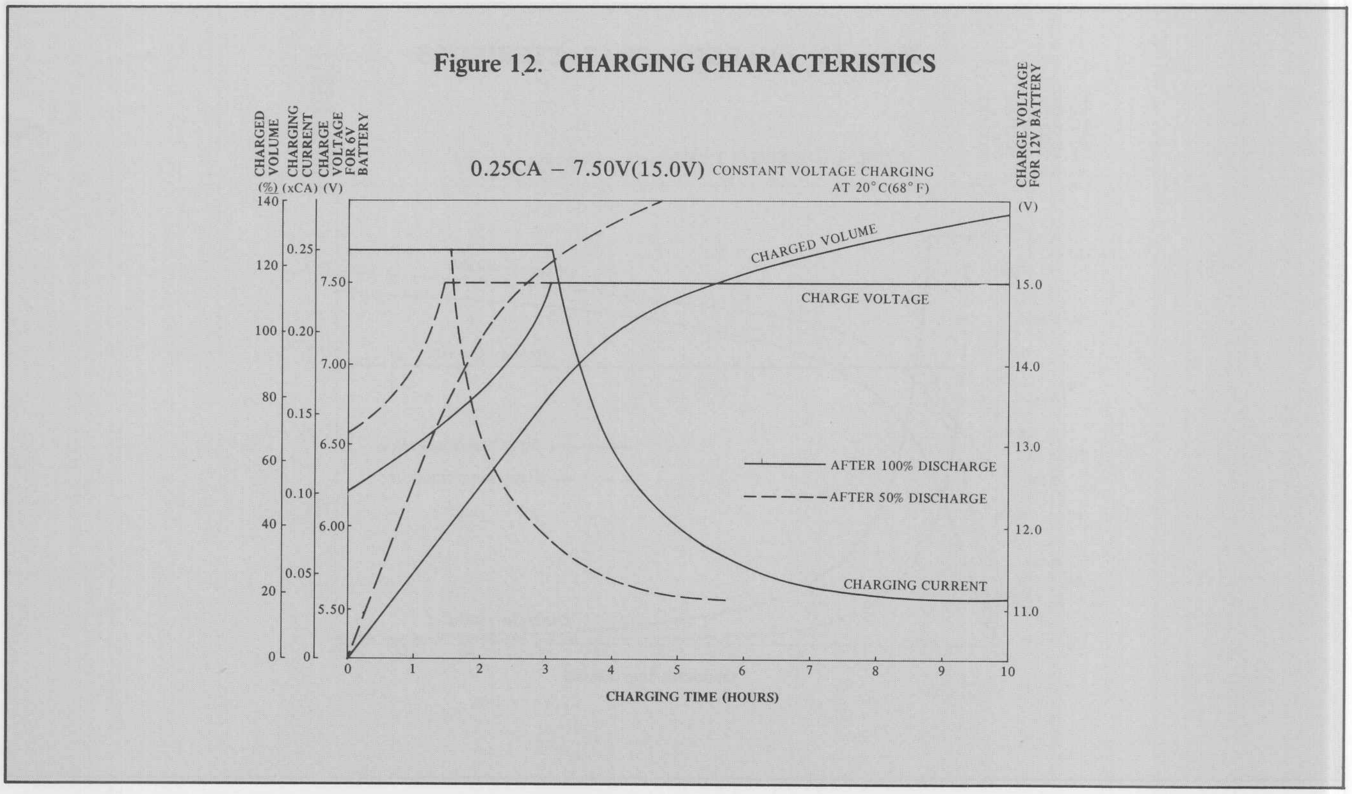


Figure 12. CHARGING CHARACTERISTICS
0.25CA – 7.50V(15.0V) CONSTANT VOLTAGE CHARGING
AT 20°C(68°F)
CHARGED VOLUME (%)
CHARGING CURRENT (xCA)
CHARGE VOLTAGE FOR 6V BATTERY (V)
CHARGE VOLTAGE FOR 12V BATTERY (V)
CHARGED VOLUME
CHARGE VOLTAGE
CHARGING CURRENT
AFTER 100% DISCHARGE
AFTER 50% DISCHARGE
CHARGING TIME (HOURS)

The charging voltage should be regulated according to the type of service in which the battery will be used. Generally, the following voltages are used:

For standby (float) use . . . . 2.25 to 2.30 volts per cell
For cyclic use . . . . 2.40 to 2.50 volts per cell

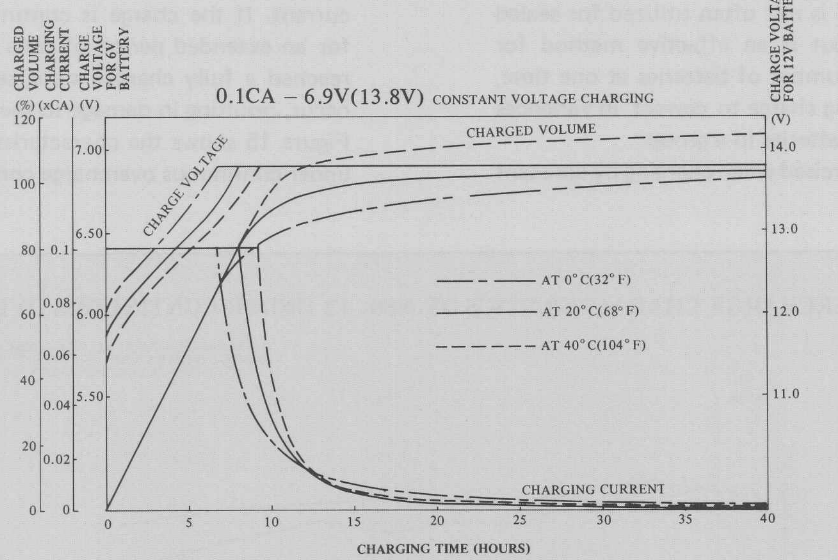
In a constant voltage charging system, a large amount of current will flow during the initial stage of charging, and decrease as the charging progresses. When charging at 2.30 volts per cell, charging current at the final stage of charging will drop to as little as 0.002 ~ 0.005CA.

The charged ampere-hours shown on the ordinate axis of Figures 7 — 12 indicates the ratio of charged ampere-hours versus the previously discharged ampere-hours. When a battery has been charged up to the level of 100% of the discharged ampere-hours, the electrical energy stored and available for discharge will be 90%, or more, of the energy applied during charging.

Charging voltage should be regulated in relation to the ambient temperature. When the temperature is higher, the charging voltage should be lower. When the temperature is lower, the charging voltage should be higher. For specific recommendations, please refer to the section on Temperature Compensation on page 19.

Similarly, charged volume (measured in ampere-hours) attainable over time will vary in direct relation to the ambient temperature. The charged volume in a given period of time will be larger at higher temperatures, and smaller at lower temperatures. Figure 13 shows the relationship between charged volume and temperature.

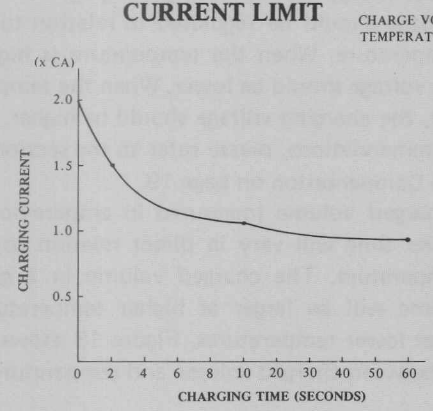
Figure 13. CHARGING CHARACTERISTICS AT DIFFERENT TEMPERATURE



INITIAL CHARGE CURRENT LIMIT

A discharged battery will accept a high charging current at the initial stage of charging. High charging current can cause abnormal internal heating which may damage the battery. Therefore, it is recommended that the charging current be normally limited to 0.25CA. However, in standby use, Yuasa NP batteries are designed so that even if the charging current is higher than the recommended limit, they will not accept more than 2CA, and the charging current will be reduced to a relatively small value in a very brief period of time. Therefore, in standby use, no current limit is required. Figure 14 shows current acceptance in NP batteries charged at constant voltage, with no current limit.

Figure 14. CONSTANT VOLTAGE CHARGE CHARACTERISTICS WITH NO CURRENT LIMIT



When designing a charger, it is recommended that a current limiting function be provided in the charger in order to prevent charger failure due to overheating of the transformer, or other damage resulting from mishandling, i.e., short circuiting or reversing polarity.

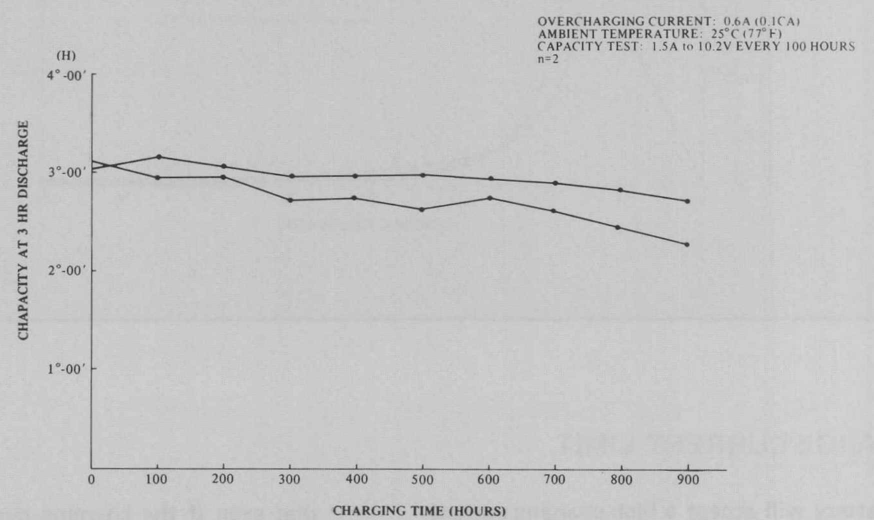
CONSTANT CURRENT CHARGING

This charging method is not often utilized for sealed lead-acid batteries, but is an effective method for charging a multiple number of batteries at one time, and/or as an equalizing charge to correct in variances in capacity between batteries in a group.

Caution should be exercised when charging by constant current. If the charge is continued at the same rate for an extended period of time after the battery has reached a fully charged state, severe overcharge may occur, resulting in damage to the battery.

Figure 15 shows the characteristics of an NP battery under continuous overcharge conditions.

Figure 15. OVERCHARGE CHARACTERISTICS OF NP6–12 UNDER CONTINUOUS OVERCHARGE



Please note that NP batteries have excellent "anti-overcharge" characteristics, therefore, brief periods of overcharge are no cause for concern.

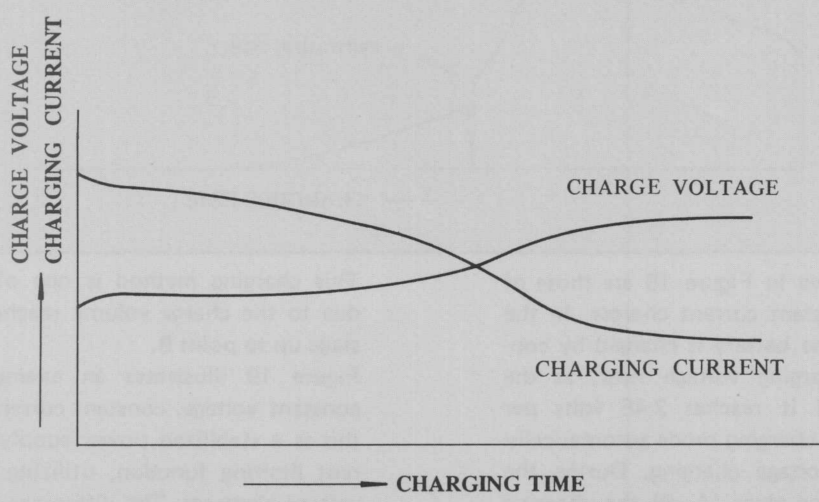
TAPER CHARGING

Due to the constant current characteristics of taper charging, this method of charging is somewhat abusive of sealed lead-acid batteries and can shorten service life. Therefore, it is not widely recommended. However, because of the simplicity of circuitry, and subsequent low cost, taper charging is extensively used to charge multiple numbers of batteries and/or for cyclic charging. When using a taper charger, it is recommended that charging time be limited, or that charging cut-off circuitry be incorporated in the charger to prevent overcharge. Please consult factory for specific recommendations.

In a taper charging circuit, the charging current decreases gradually and charging voltage rises proportionately as the charge progresses. When designing a taper charger please keep in mind that when the power source is the actual commercial power supply, the voltage will fluctuate due to fluctuations in the commercial supply, and the charging current will fluctuate over a broad range as a consequence. In addition, in a taper charger, the I^2R drop converts to heat. Therefore, heat generated by the circuit should be measured, and if necessary, a heat sink incorporated in the design.

Figure 16 Illustrates the characteristics of a typical taper charger.

Figure 16. CHARGING CHARACTERISTICS OF A TAPER CHARGER

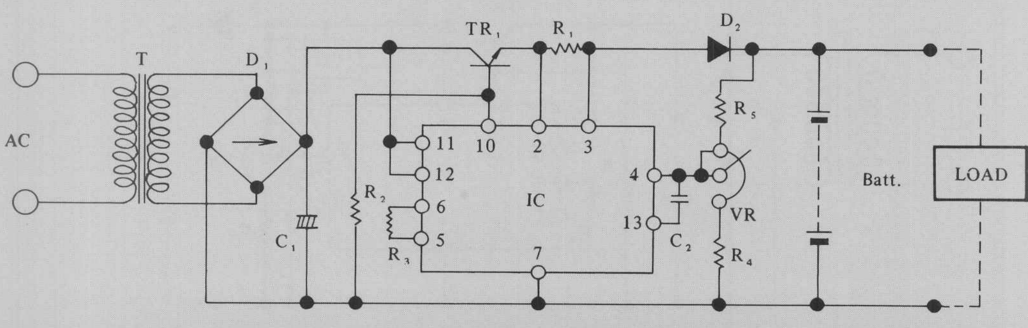


RECOMMENDED CHARGING CIRCUITS

Constant Voltage Charge Circuit

Figure 17 shows one example of a constant voltage charging circuit. In the circuit, initial charging current is limited by series resistance R_1.

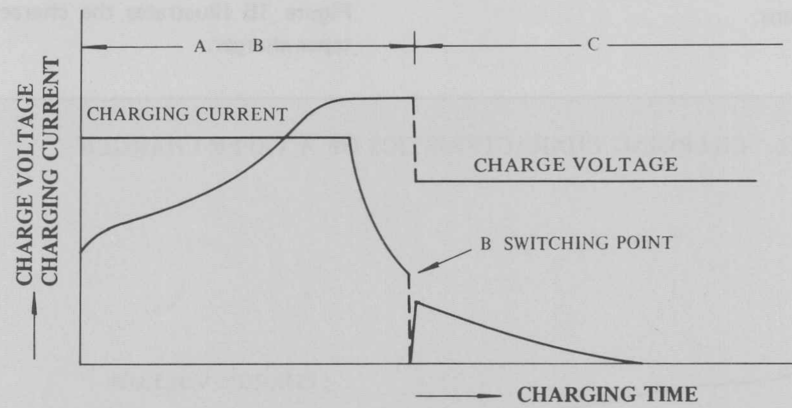
Figure 17. ONE EXAMPLE OF CONSTANT VOLTAGE CHARGING CIRCUIT



Two Step Constant Voltage Charge Circuit

Two step constant voltage charging is the recommended method for charging a sealed lead-acid battery in a short period of time, and maintaining the battery in a fully charged standby or float condition, thereafter. Figure 18 illustrates the characteristics of a two step constant voltage charger.

Figure 18. CHARGING CHARACTERISTICS OF A TWO STEP CONSTANT VOLTAGE CHARGER

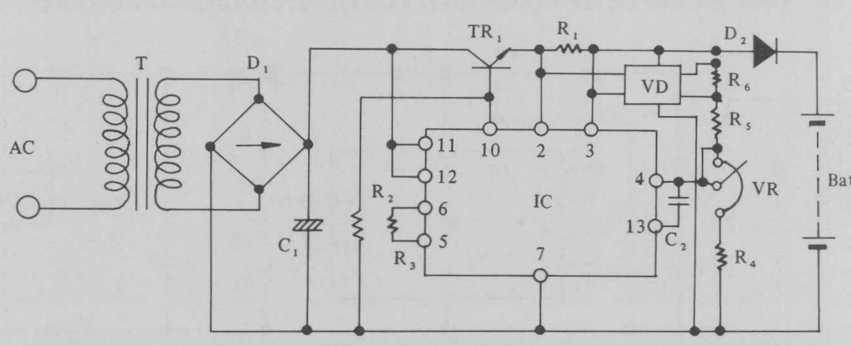


The characteristics shown in Figure 18 are those of a constant voltage, constant current charger. In the initial charging stage, the battery is charged by constant current. The charging voltage rises, as the charge continues, until it reaches 2.45 volts per cell, at which point the charging mode automatically changes to constant voltage charging. During the constant current charging stage (A–B) the charging current which has decreased to point B is sensed, and the charging voltage is switched to the float level of 2.3 volts per cell from the recovery level (B–C) of 2.45 volts per cell. The switch to constant voltage trickle charging occurs after the battery has recovered approximately 80% of the rated capacity over a given period of time.

This charging method is one of the most efficient due to the charge volume reached during the initial stage up to point B.

Figure 19 illustrates an example of a two step constant voltage, constant current charger. Basically, this is a stabilized power supply circuit, with a current limiting function, utilizing hybrid IC constant voltage elements. The difference between this circuit and the constant voltage circuit shown in Figure 17 is the addition of circuit VD which serves to increase or decrease the output voltage as a function of the variation in output current. In other words, the output voltage is established by changing, with resistor R_6, the potential ratio of the detected voltage of the IC which detects the reduction of voltage at both terminals of resistor R_1.

Figure 19. ONE EXAMPLE OF A TWO STEP CONSTANT VOLTAGE CONSTANT CURRENT CHARGING CIRCUIT



When this charging method is used, the output values will be as follows:

Initial Charge Current . . . 0.25CA (to 1.0CA, max.)

Charge Voltage —

1st Step . . . 2.45v/cell (2.40 to 2.50v/cell, max.)

2nd Step . . . 2.30v/cell (2.25 to 2.30v/cell, max.)

Switching Current From

1st Step to 2nd Step . . 0.05CA (0.04 to 0.08CA)

Note: This charging method cannot be used in applications where the load and the battery are connected in parallel.

Figure 20 shows a typical constant current charging circuit.

Figure 21 shows typical taper charging circuits.

Figure 20. CONSTANT CURRENT CHARGING CIRCUIT

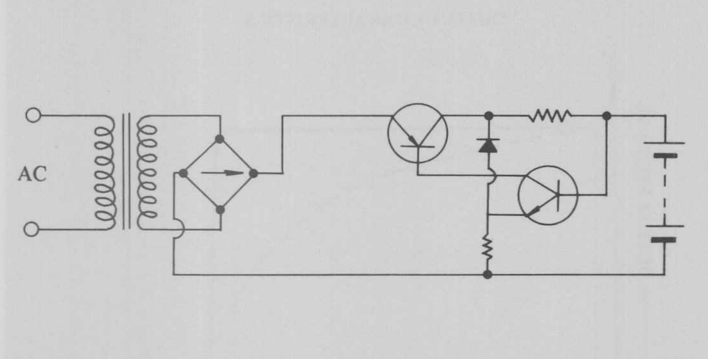
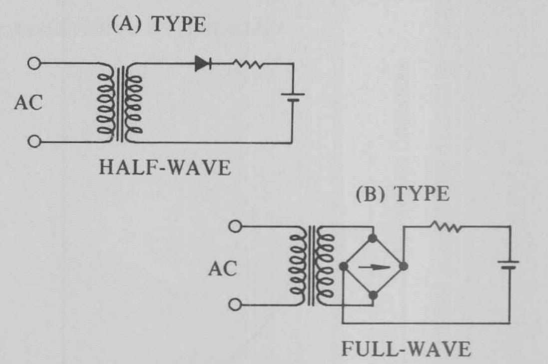


Figure 21. TAPER CHARGING CIRCUITS



YUASA C.V.C.C. CONSTANT VOLTAGE, CONSTANT CURRENT CHARGE UNIT

The Yuasa C.V.C.C. is a fully regulated automatic charging module designed for NP batteries in both standby and cyclic applications.

When interfaced with the appropriate AC or DC power supply, the Yuasa C.V.C.C. guarantees safe charging and maximum battery life. Figure 22 is a block diagram of the C.V.C.C.

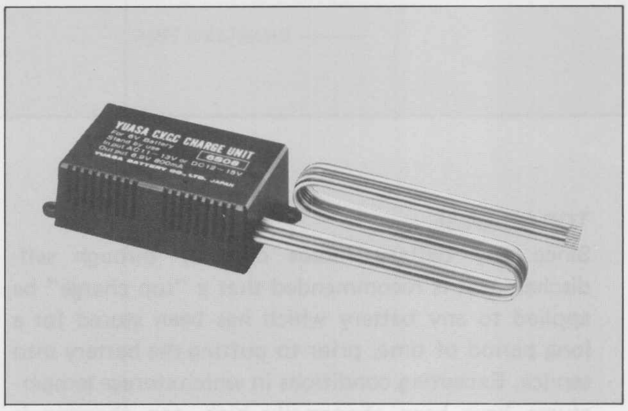
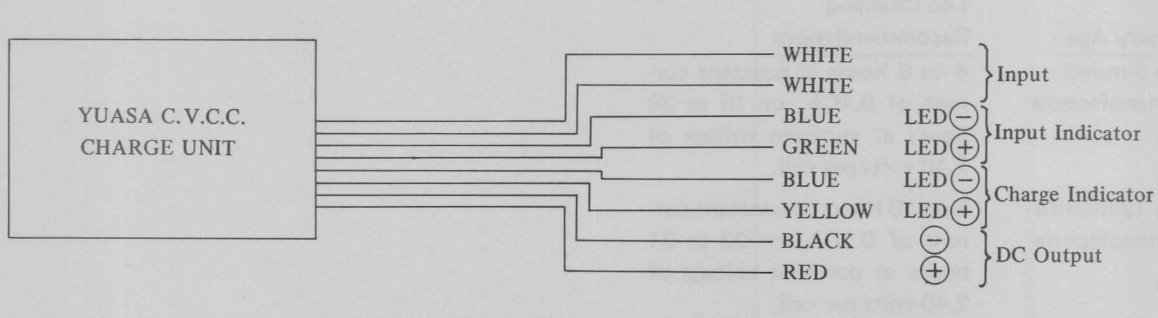


Figure 22. BLOCK DIAGRAM OF C.V.C.C.



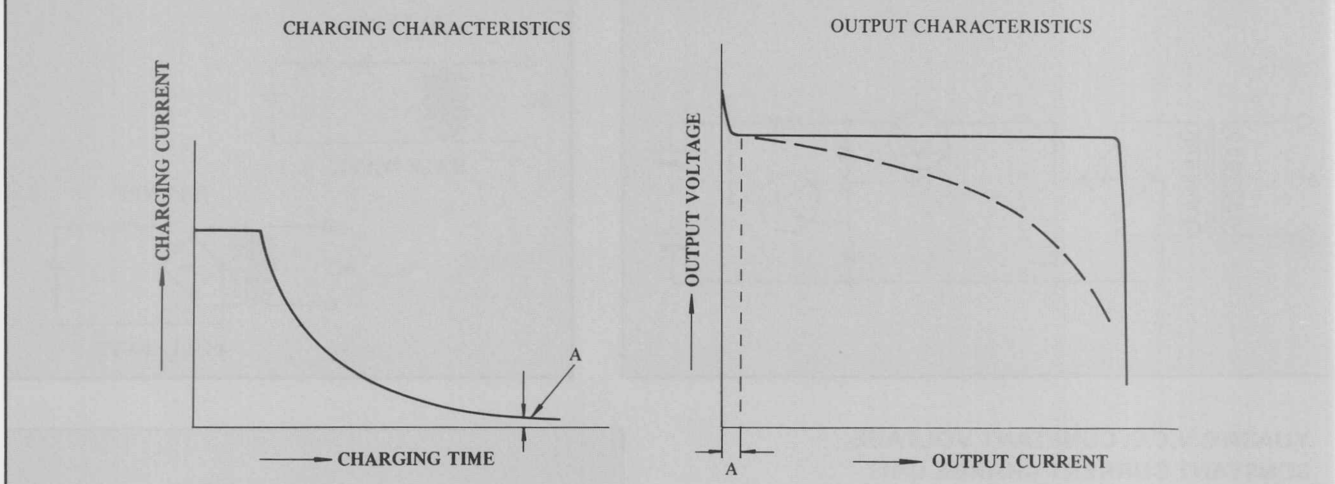
No damage can be caused to the C.V.C.C. by short circuiting, or reversed battery polarity.

Detailed specifications are available upon request.

CHARGER OUTPUT REGULATION AND ACCURACY

To insure accuracy, when adjusting the output voltage of a constant voltage charger, all adjustments must be made with the charger under load. Adjusting the output voltage with the charger in a "NO LOAD" condition may result in undercharging. The constant voltage range required by a battery is always defined as the voltage range applied to a battery which is fully charged. Therefore, a charger having the output characteristics illustrated in Figure 23, should be adjusted with the output voltage based on point A. The most important factor in adjusting charger output voltage is the accuracy at point A. Stringent accuracy of 2.25 to 2.3 volts per cell (±1.0%) is not required over the entire range of the load. A charger adjusted in accordance with Figure 23 will never damage a battery, even if the charger has the characterisitcs shown by the broken line in Figure 23.

Figure 23. OUTPUT VOLTAGE ADJUSTMENT



TOP CHARGE

Since any battery looses capacity through self-discharge, it is recommended that a "top charge" be applied to any battery which has been stored for a long period of time, prior to putting the battery into service. Excepting conditions in which storage temperatures have been abnormally high, top charging is recommended within the following parameters:

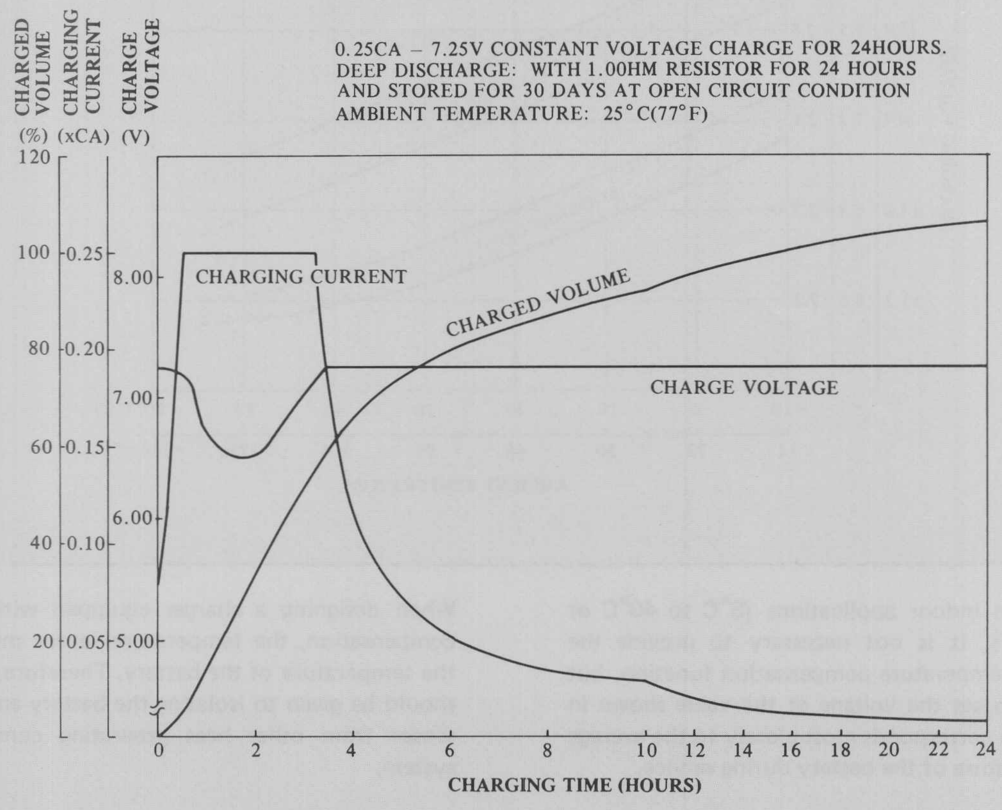
Battery Age	Top Charging Recommendations
Within 6 months after manufacture	4 to 6 hours at constant current of 0.1CA, or 15 to 20 hours at constant voltage of 2.40 volts per cell.
Within 12 months after manufacture	8 to 10 hours at constant current of 0.1CA, or 20 to 24 hours at constant voltage of 2.40 volts per cell.

In order to successfully top charge a battery stored for more than 12 months, the open circuit voltage must be higher than 2.0 volts per cell. In this case, always confirm open circuit voltage prior to attempting top charging.

RECOVERY CHARGE AFTER DEEP DISCHARGE

When a battery has been subjected to deep discharge (commonly referred to as overdischarge), the amount of electricity which has been discharged is actually 1.5 to 2.0 times as great as the rated capacity of the battery. Consequently, a battery which has been over-discharged requires a longer charging period than normal. Please note, as shown in Figure 24 below, that as a result of internal resistance, charging current accepted by an overdischarged NP battery during the initial stage of charging will be quite small, but will increase rapidly over the initial 30 minutes (approximate) until internal resistance has been overcome, and normal, full recovery charging characteristics resume.

Figure 24. CHARGING CHARACTERISTICS OF NP 10-6 AFTER DEEP DISCHARGE



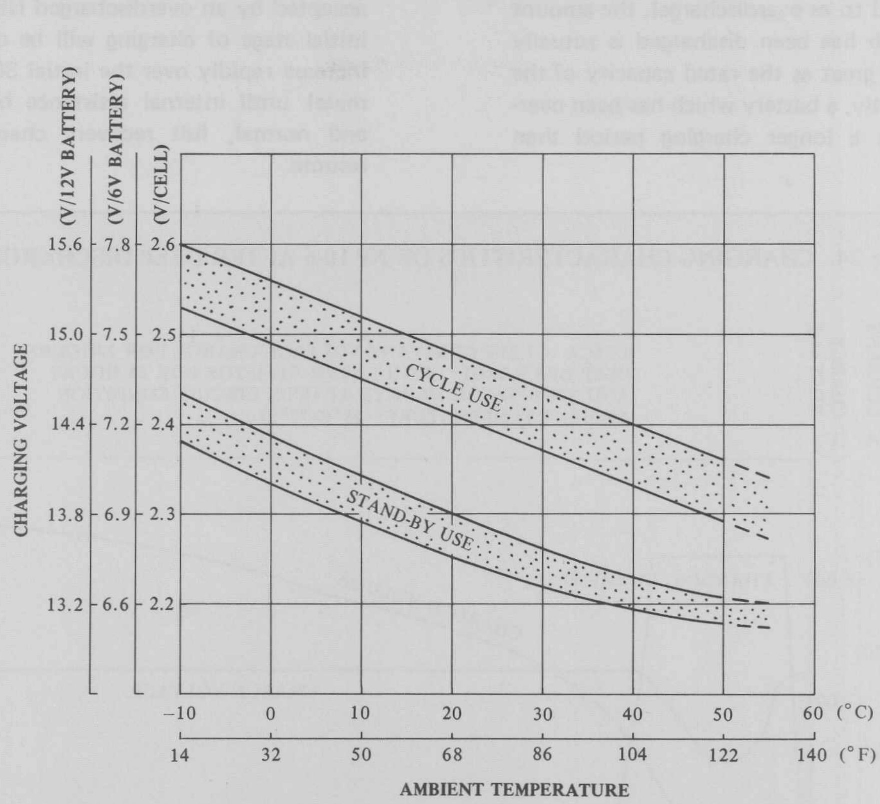
In view of the above, consideration should be given to the fact that if the charging method used is constant voltage in which the charger employs current sensing for either state of charge indication or for reducing voltage (a two step charger), during the initial stage of charging an overdischarged battery, the charger may give a false "full charge" indication, or may initiate charge at a float voltage.

TEMPERATURE COMPENSATION

As temperature rises, electrochemical activity in a battery increases. Similarly, as temperature falls, electrochemical activity decreases. Therefore, conversely, as temperature rises, charging voltage should be reduced to prevent overcharge, and increased as temperature falls to avoid undercharge. In general, to assure optimum service life, use of a temperature compensated charger is recommended. The recommended compensation factor for NP batteries is ±4mV/°C/Cell. The standard center point for temperature compensation is 20°C.

Figure 25 shows the relationship between temperatures and charging voltages in both cyclic and standby applications.

Figure 25. RELATIONSHIP BETWEEN CHARGING VOLTAGE AND TEMPERATURE



In actual use in indoor applications (5°C to 40°C or 41°F to 104°F), it is not necessary to provide the charger with a temperature compensation function, but it is desirable to set the voltage at the value shown in Figure 25 which corresponds most closely to the average ambient temperature of the battery during service.

When designing a charger equipped with temperature compensation, the temperature sensor must sense only the temperature of the battery. Therefore, consideration should be given to isolating the battery and temperature sensor from other heat generating components of a system.

CHARGE EFFICIENCY

The charge efficiency (η) of a battery is expressed by the following formula:

$$\eta = \frac{\text{AH Discharged After Charged}}{\text{AH Delivered To The Battery During Charge}}$$

The charge efficiency varies depending upon the state of charge of the battery, temperatures, and charging rates.

Figure 26 illustrates the concept of the state of charge and charge efficiency.

As shown in Figure 27, Yuasa NP batteries exhibit very high charge efficiency, even when charged at low charging rates. It is interesting to note that the charging efficiency of NP sealed lead-acid batteries is superior to that of nickel cadmium batteries even at relatively low charge rates.

Figure 26. CHARGE EFFICIENCY VS STATE OF CHARGE

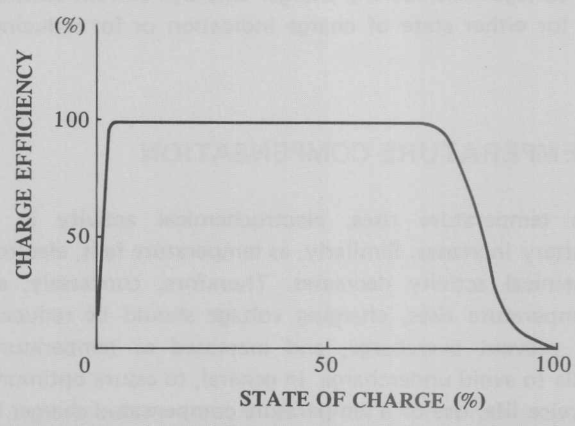
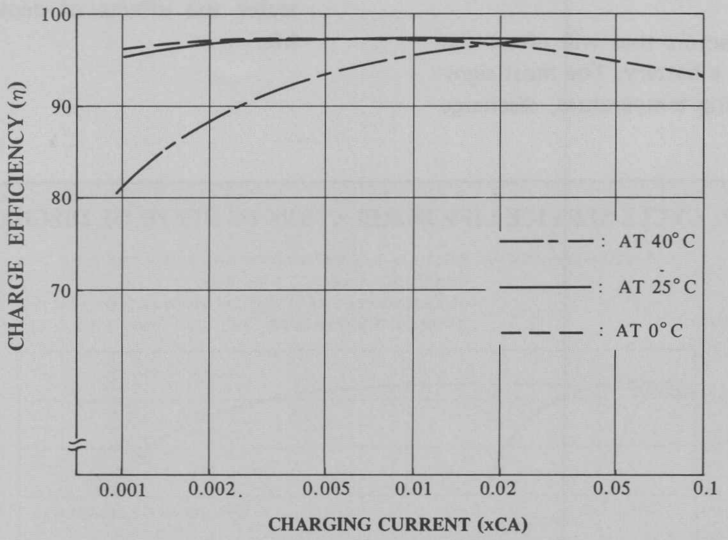


Figure 27. CHARGE EFFICIENCY



SOLAR POWERED CHARGERS

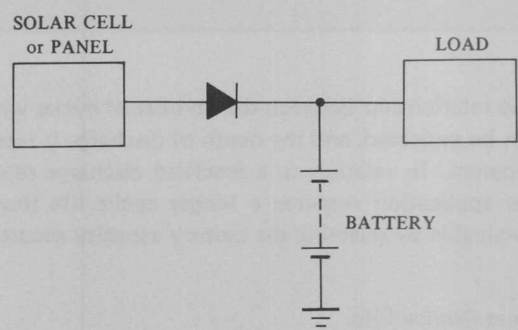
A battery is an indispensable component of any solar powered system designed for demand-energy use. Since solar cells have inherent constant voltage characteristics, NP batteries can be charged directly from the solar array using a simple diode regulated circuit as shown in Figure 28.

In designing a solar system, consideration should be given to the fact that, in addition to normal periods of darkness, weather conditions may be such that solar energy is limited, or virtually unavailable for long periods of time. In extreme cases, a system may have to operate for 10 to 20 days with little or no power available for charging. Therefore, when selecting the correct battery for a solar application, the capacity should be determined based upon maximum load conditions for the maximum period of time the system may be expected to be without adequate solar input.

In many instances the battery capacity will be 10 to 50 times greater than the maximum output of the solar panels. Under these circumstances, the maximum output of the solar array should be dedicated to charging the battery with no load-sharing or intervening control devices of any kind.

Naturally, in cases where the output of the solar array exceeds the capacity of the battery, and weather conditions are such that the potential for overcharging the battery exists, appropriate regulated charging circuitry between the solar panels and the battery is recommended.

Figure 28. BLOCK DIAGRAM OF A SOLAR SYSTEM



Remote site, or other outdoor applications for solar systems is commonplace. When designing a solar system for this class of application, a great deal of consideration must be given to environmental conditions. For example, enclosures which may be used to house batteries and other equipment may be subject to extremely high internal temperatures when exposed to direct sunlight. Under those conditions, insulating the enclosure and/or treating the surface of the enclosure with a highly reflective, heat resistive material is recommended.

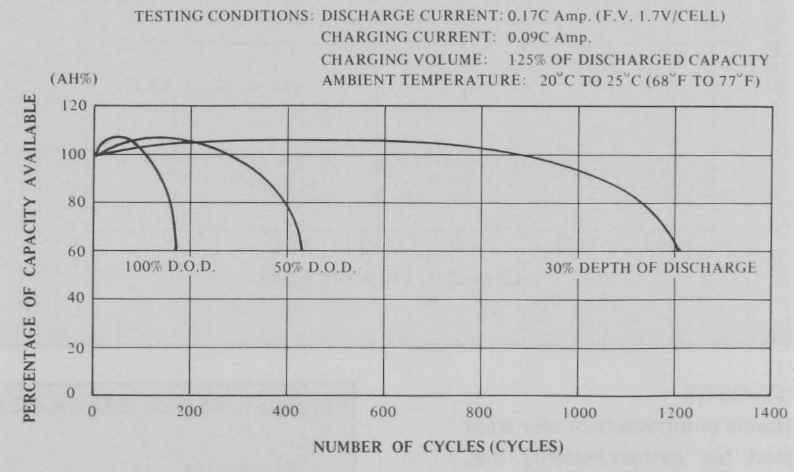
In general, when designing a solar system, consultation with the solar panel manufacturer and battery manufacturer is recommended.

EXPECTED SERVICE LIFE OF NP BATTERIES

Cyclic Service Life

There are a number of factors that will effect the length of cyclic service of a battery. The most significant are ambient operating temperature, discharge rate, depth of discharge, and the manner in which the battery is recharged. Generally speaking, the most important factor is depth of discharge. Figure 29 illustrates the effects of depth of discharge on cyclic life.

Figure 29. CYCLE SERVICE LIFE IN RELATION TO DEPTH OF DISCHARGE

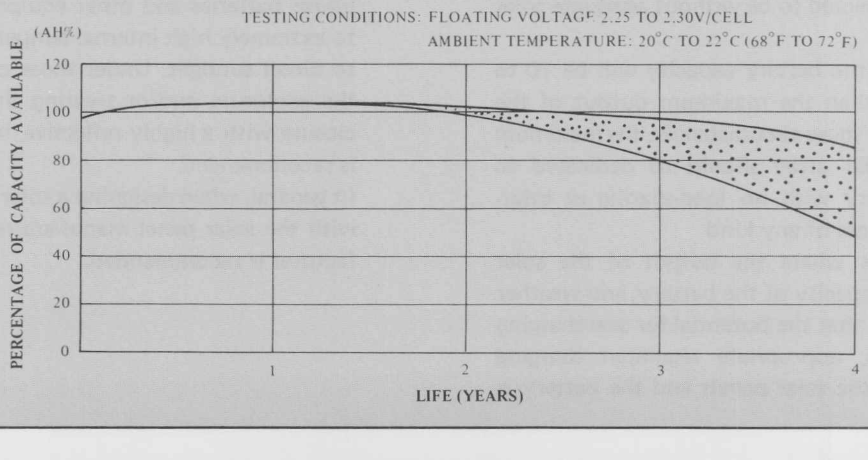


The relationship between the number of cycles which can be expected, and the depth of discharge is readily apparent. In relation to a specified discharge rate, if the application requires a longer cyclic life than is obtainable by selecting the battery capacity according to the general rule of discharge rate vs. time, it is common practice to select a battery with larger capacity. Thus, at the specified discharge rate over the specified time, the depth of discharge will be shallower and cyclic service life will be longer.

Float Service Life

NP batteries are designed to operate in standby (float) service for approximately 5 years, based upon a normal service condition in which float charge voltage is maintained between 2.25 and 2.30 volts per cell in an ambient temperature of approximately 20°C (68°F). Figure 30 shows the float service life characteristics of NP batteries when discharged once every three (3) months to 100% depth of discharge.

Figure 30. FLOAT SERVICE LIFE



In normal float service, where charging voltage is maintained at 2.25 to 2.30 volts per cell, the gases generated inside an NP battery are continually re-combined into the negative plates, and return to the water content of the electrolyte. Therefore, electrical capacity is not lost due to "drying up" of the electrolyte. Actually, through the gradual and very slow corrosion of the electrodes, the battery will eventually lose capacity and come to the end of service life. It should be noted that the corrosive process will be accelerated by high ambient operating temperatures and/or high charging voltage. When designing a float service system, always consider the following:

LENGTH OF SERVICE LIFE WILL BE DIRECTLY EFFECTED BY THE NUMBER OF DISCHARGE CYCLES, DEPTH OF DISCHARGE, AMBIENT TEMPERATURE, AND CHARGING VOLTAGE.

PERIODIC SYSTEM CHECK

Yuasa NP batteries are completely maintenance free. However, when batteries are used in float service, a periodic check is recommended to ensure system reliability, particularly in systems employing more than one battery.
The recommended periodic check should include:

1. Confirmation of correct charger output.
2. Charging voltage of each battery.
3. Physical check of harness and connectors.
4. Load test using actual or simulated load.

Parallel Connection

Yuasa NP series batteries may be used in parallel connection for obtaining higher capacity.
When connecting batteries to form a battery group in parallel connection, the following inspection and handling procedures are required.

1. Measure the terminal voltage of each battery to be used in the parallel connection.
   The terminal voltage of each battery selected must be 2.1 volts per cell or higher (6.3 volts or higher for 6 volts type betteries and 12.6 volts or higher for 12 volts type batteries)
   If a battery has a terminal voltage of less than 2.1 volts per cell, an equalizing charge is necessary before that battery can be included in the battery group for parallel connection.
2. It is essential to use uniform connectors and/or cable of sufficient gauge to carry the specified DC load.
3. If 2 or more battery groups are used in parallel connection, they must be connected to the load through equal lengths of cable and each cable must be equipped with a fuse.
4. When connecting a battery, free air space must be provided between each of the batteries. The minimum recommended spacing between batteries is 0.04 inches (10mm) to 0.6 inches (15mm).
5. When assembling 240 volt battery groups, maximum performance will be obtained by limiting parallel connections to 3 lines or less.

GLOSSARY

Term	Definition
1. Ampere	A unit for measuring electric current.
2. Ampere Hour (AH)	Current (amperes) multiplied by time. Used to indicate the capacity of a battery.
3. Capacity	Ampere hours that can be discharged from a battery.
4. Cell	The minimum unit of which a battery is composed, consisting of positive and negative plates, separators, electrolyte, etc. In sealed lead-acid batteries, nominal voltage is 2 volts per cell.
5. Charging	The process of putting electric energy into a battery for storage in the form of chemical energy.
6. Current	The amount of electric charge flowing past a specified circuit point per unit time. Measured in amperes.
7. Cycle	One full discharge followed by one full charge of a battery.
8. Cycle Service	The use of a battery with alternate repetition of charging and discharging.
9. Cycle Service Life	The total number of cycles expected at a given depth of discharge.
10. Deep Discharge	a) Discharge of a battery until 100% of the capacity is exhausted. b) Discharge of a battery until the voltage under load drops below the specified final discharge voltage. (Overdischarge)
11. Depth of Discharge	The ratio of discharged capacity vs. rated capacity of a battery.
12. Discharge	The process of drawing stored energy out of a battery.
13. Energy Density	The ratio of energy that can be discharged from a battery to the volume of a battery. Measured in Watt Hours (WH) per cubic inch, or litre.
14. Float Service	Method of use in which the battery and the load are connected to a rectifier in parallel so that constant voltage is applied to the battery continuously, maintaining the battery in a fully charged state, and to supply power to the load from the battery without interruption or load variation.
15. Gas Recombination	The process by which oxygen gas generated from the positive plates during the final stage of charging is absorbed into the negative plates, and the negative plates become chemically discharged, suppressing the generation of hydrogen.
16. Impedance	The ratio of current variation vs. voltage variation in alternating current.
17. Internal Resistance	The term given to the resistance inside a battery, consisting of the sum of resistance of electrolyte positive and negative plates, separators, etc.
18. Life Expectancy	Expected service life of a battery expressed in total cycles or time in float service in relation to a specified application.
19. Load	The amount of current required for an application. Measured in amperes.
20. Nominal Capacity	The nominal value of rated capacity. In sealed lead-acid batteries nominal capacity is measured at a 20 hour rate.

21. Nominal Voltage	The nominal value of rated voltage. In lead-acid batteries, nominal voltage is 2 volts per cell.
22. Open Circuit Voltage	The voltage of a battery which is isolated electrically from any external circuit, i.e., the voltage is measured in a no load condition.
23. Parallel Connection	Connection of a group of batteries by interconnecting all terminals of the same polarity, thereby increasing the capacity of the battery group.
24. Positive Plate	A positively charged plate from which current flows during discharge.
25. Recovery Charge	The process of charging a discharged battery to restore its capacity in preparation for subsequent discharge.
26. Self Discharge	Loss of capacity without external current drain.
27. Series Connection	Connection of a group of batteries by interconnecting terminals of opposite polarity, thereby increasing the voltage of the battery group.
28. Shallow Discharge	Discharge of a battery in which discharge is terminated above 50% depth of discharge.
29. Shelf Life	The maximum period of time a battery can be stored, under specified conditions, without supplementary charging.
30. Specific Energy	The ratio of energy that can be discharged from a battery to the weight of a battery. Measured in Watt Hours (WH) per pound, or kilograms.
31. Standby Service	General term for an application in which the battery in maintained in a fully charged condition by trickle or float charging. Synonomous with Float Service.
32. Trickle Charge	Continuous charging by means of a small current designed to compensate for self discharge in a battery which is isolated from any load. Both constant current and constant voltage charging methods are common.
33. Watt Hour (WH)	Energy which can be discharged, expressed in Watts per Hours.

YUASA BATTERY CO., LTD.

INTERNATIONAL POWER SYSTEMS DIVISION

12-11, Higashi-Shimbashi 2-Chome
Minato-ku, Tokyo, 105, Japan
Phone: Tokyo (03) 437-2411
Cable : YUASABATRY TOKYO
Telex : YBCTOK A J29228
Facsimile: Tokyo (03) 433-7375

OVERSEAS AFFILIATES

Yuasa Battery (America), Inc.
9728 Alburtis Avenue
Santa Fe Springs CA 90670, U.S.A.
Phone: 213-949-4266

Yuasa Battery (Europe) GMBH
Shadow Strasse 39
4000 Dusseldorf
F.R. Germany
Phone: 0211-350047

Yuasa Battery (UK) Ltd.
Unit 22 Rassau Industrial Estate
EBBW Vale, GWENT NP 3 5SD
United Kingdom
Phone: 0495-306121

Yuasa Battery Sales (UK) Ltd.
Hawksworth Industrial Estate
Swindon, Wiltshire SN2 1DZ
United Kingdom
Phone: 0793-486818

Cat. No. NP—100 April. 1985 Printed in Japan ©